Manual for the Balancing Power Dimensioning Tool

Outline

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1 Overview of the tool

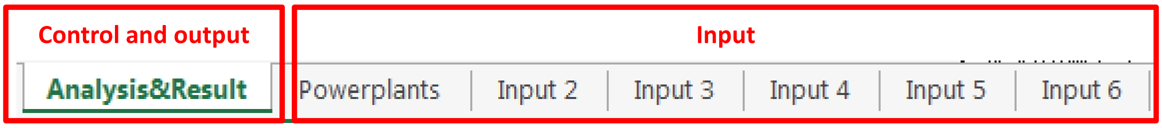
1.1 What the tool does

The tool calculates the cumulated imbalance distribution function of power plant outages and other forecast errors, such as wind, PV and load forecast errors. This is done by a recursive combination of up to 6 different distributions. Given the cumulated imbalance distribution, the tool also calculates the amount of balancing power that is required given a specific security level.

The tool is written in MS Excel using Visual Basic for Applications (VBA). To access the VBA code, you can press [Alt]-[F11].

1.2 Sheets in the tool

The tool consists of seven sheets. The first sheet is called "Analysis&Results", which is the main sheet. It contains both the control buttons to perform the calculations and the output of the calculations. The other sheets are input sheets. The sheet "Powerplants" contains the generation capacities of the power plants and each power plant's dropout probability. The sheets "Input 2" to "Input 6" may contain additional distributions, such as wind, PV or load forecast errors. The names of these sheets can changed. However, their order cannot be changed and two sheets cannot have the same name.



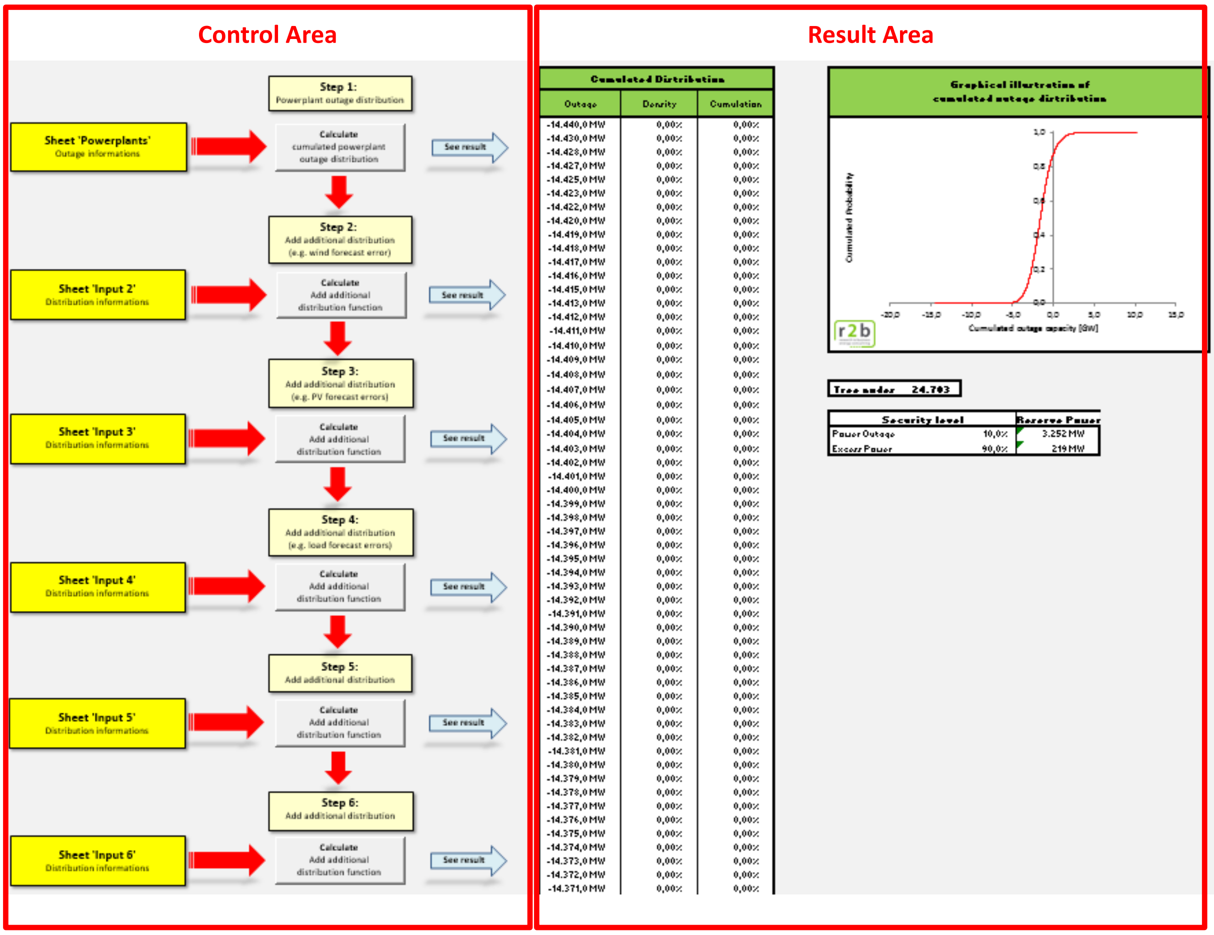
1.3 General procedure

The general procedure of calculating the cumulated distribution is subsumed in the following:

1. Enter the power plants and their outage probabilities into the sheet "Powerplants"
2. Calculate the cumulated power plant outage distribution
3. Enter the first additional distribution (e.g. wind forecast error) into the sheet "Input 2" (or whatever its name is)
4. Calculate the cumulated imbalance distribution by adding the first additional distribution
5. Perform step 3 and 4 for up to four other additional distributions (e.g. PV or load forecast errors) by using the sheets "Input 3" to "Input 6"

1.4 The main sheet

The tool is controlled via the sheet "Analysis&Results". The sheet is divided into two areas: The control area on the left and the result area on the right.



The control area contains yellow buttons labelled as "Sheet 'Powerplants' Outage informations", "Sheet 'Input 2' Distribution informations" and so forth on the left. By pressing one of these buttons, you will be directed to the respective sheet, where you can enter data. On the right of each of these yellow buttons there is a grey button labelled as "Calculate […]". By pressing this button, the respective distribution will be added to the cumulative imbalance distribution.

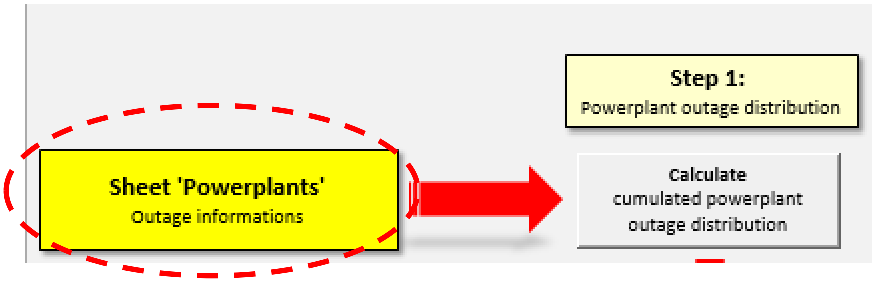
The result area contains the cumulated imbalance distribution, i.e. a recursive combination of all distributions added so far. It shows the generation capacities in the left column and the respective probability density ("How likely is it that this amount of generation capacity is not available?") in the middle column. The right column is the cumulative probability ("How likely is it that *at least* this amount of generation capacity is not available?"). There is also a graphical representation of the cumulative distribution function at the top on the right. Below this graphical representation, the tool shows the overall amount of nodes in the distribution and below that it shows the amount of positive and negative reserve power that is required given a specific security level.

2 Details how to use the tool

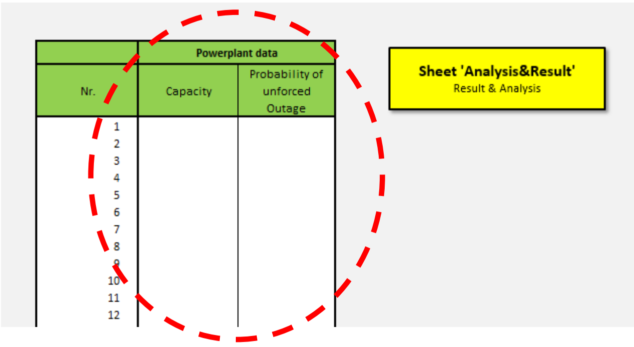
In the following, the process of how to use the tool will be described. The whole process is controlled via to the sheet "Analysis&Results". Therefore, please start by activating this sheet.

2.1 Step 1: Adding power plants

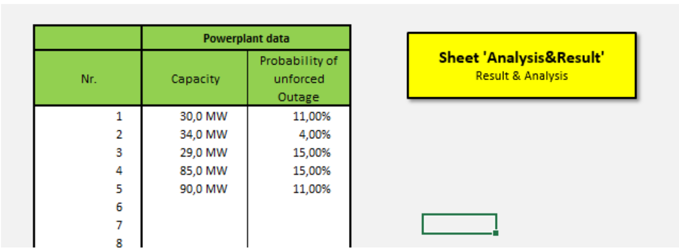
The first step is to add the power plants and their outage probabilities. To do so, klick the yellow button (“Sheet ‘Powerplants’ Outage informations”):



This will lead you to the sheet “Powerplants”, where you can add up to 100 power plants. Each power plant consists of its generation capacity and the probability of unforced outage. Enter the capacities and outage probabilities to the sheet:

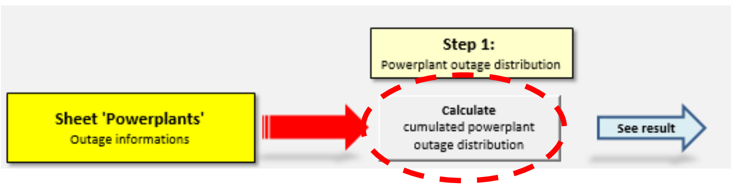


In this example our system consists of five power plants:



When you have finished adding your power plants, klick the yellow button to return to the sheet “Analysis&Results”.

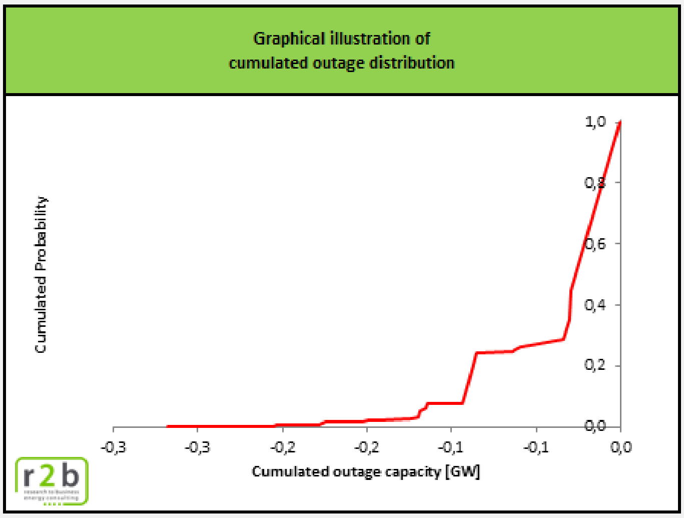
In order to calculate the cumulated outage distribution of the power plants, you must now press the “Calculate”-button under step 1:



The tool will now calculate the cumulated outage distribution of the power plants you just added. Note: Any existing cumulated distribution will be deleted! The result can be seen in the right part of

the sheet “Analysis&Results”:

Cumulated Distribution		
Outage	Density	Cumulation
-268,0 MW	0,00%	0,00%
-239,0 MW	0,01%	0,01%
-238,0 MW	0,01%	0,02%
-234,0 MW	0,03%	0,04%
-209,0 MW	0,05%	0,09%
-205,0 MW	0,15%	0,24%
-204,0 MW	0,21%	0,45%
-183,0 MW	0,01%	0,46%
-178,0 MW	0,01%	0,47%
-175,0 MW	1,20%	1,66%
-154,0 MW	0,03%	1,70%
-153,0 MW	0,05%	1,75%
-149,0 MW	0,20%	1,95%
-148,0 MW	0,07%	2,02%
-144,0 MW	0,21%	2,23%
-124,0 MW	0,28%	2,51%
-120,0 MW	0,84%	3,35%
-119,0 MW	1,60%	4,96%
-115,0 MW	1,20%	6,15%
-114,0 MW	1,71%	7,86%
-93,0 MW	0,05%	7,91%
-90,0 MW	6,79%	14,70%
-85,0 MW	9,70%	24,40%
-64,0 MW	0,28%	24,68%
-63,0 MW	0,40%	25,09%
-59,0 MW	1,20%	26,29%
-34,0 MW	2,29%	28,57%
-30,0 MW	6,79%	35,36%
-29,0 MW	9,70%	45,06%
0,0 MW	54,94%	100,00%



Tree nodes	30

Security level		Reserve Power
Power Outage	10,0%	93 MW
Excess Power	90,0%	MW

The cumulated outage distribution is shown in the table on the left. In this example, it consists of 30 nodes. For example, the probability that at least 268 MW drop out is 0 %. The probability, that at least 239 MW drop out is 0.01 % and so forth. The probability that at least 29 MW drop out is 45.06 % and the probability that at least 0 MW drop out is 100 %. This cumulated distribution is also shown in the graphic at the top on the right.

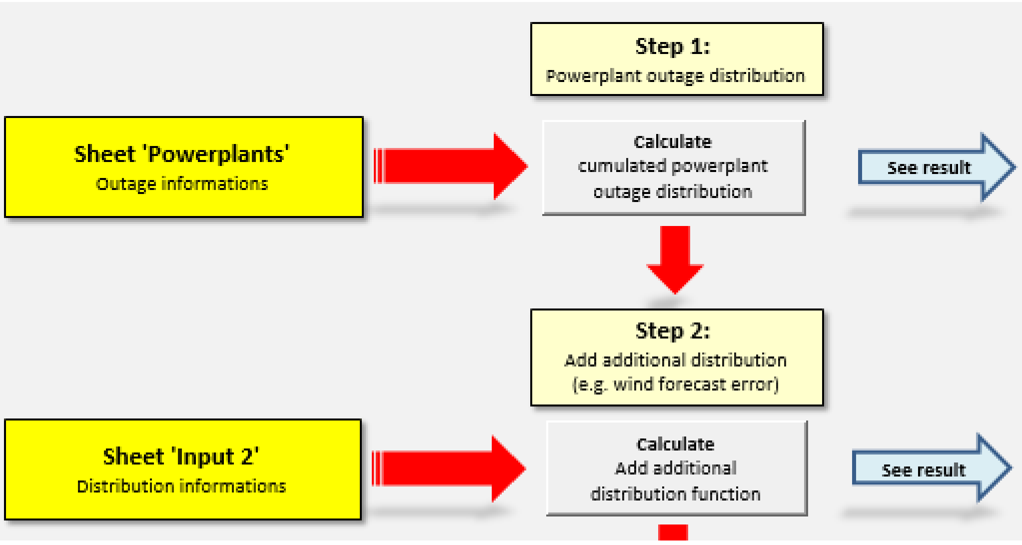
At the bottom on the right you can see that this leads to a power outage of 93 MW and thus a requirement of 93 MW of positive reserve if a security level of 10 % is desired. The amount of reserve power that is required corresponds to the lower (negative) and upper (positive) quantile of the cumulated distribution. You can change the security level entering in a different number. For instance, if a security level of 5 % is desired, in this example 119 MW of positive reserve are required:

Security level		Reserve Power
Power Outage	10,0%	93 MW
Excess Power	90,0%	MW

Note: Since power plant outages always require positive reserve, there is no need for negative reserve so far. The tool therefore calculates zero MW negative reserve power. However, under certain circumstances (i.e. when there are many power plants involved or when you choose a very low security level) it can happen, that even a “negative” amount (e.g. -50 MW) of negative reserve power is calculated. This is, however, only a theoretical result.

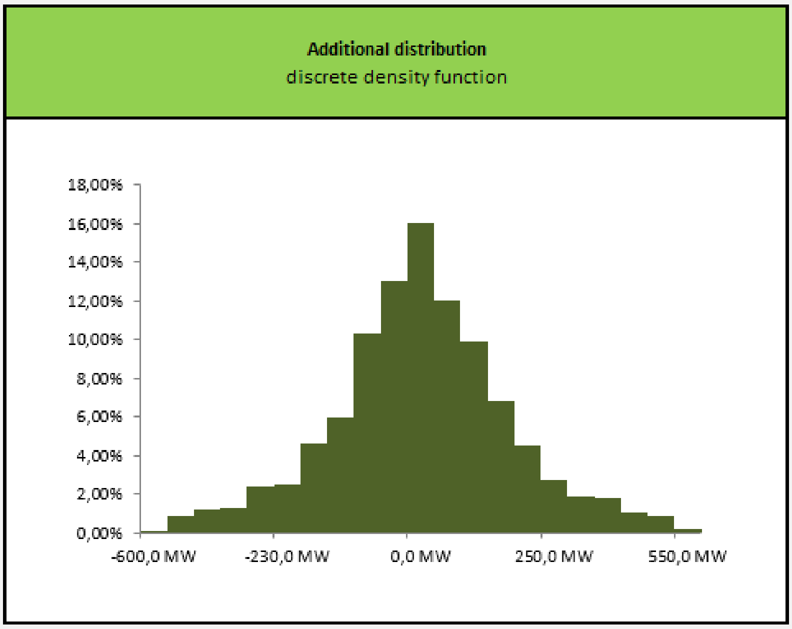
2.2 Step 2: Adding an additional distribution

In the next step, additional distributions can be added to the cumulated distribution. First, klick on the yellow button to go to the sheet for the first additional distribution:



This sheet is originally labelled “Input 2”, but the name of the sheet – like all names of the sheets for additional distributions – can be changed (for instance to “Wind forecast error” or whatever name is desired. Please note that all sheets need to have different names and that their order cannot be changed, i.e. sheet “Input 2” must always be left of “Input 3” and so on. In this sheet (“Input 2”) you can now add an additional distribution. This can, for instance, be the distribution of wind forecast errors. For each error, you can add the specific probability of its occurrence. The distribution can consist of up to 21 values and the sum of all probabilities must add to 100 %:

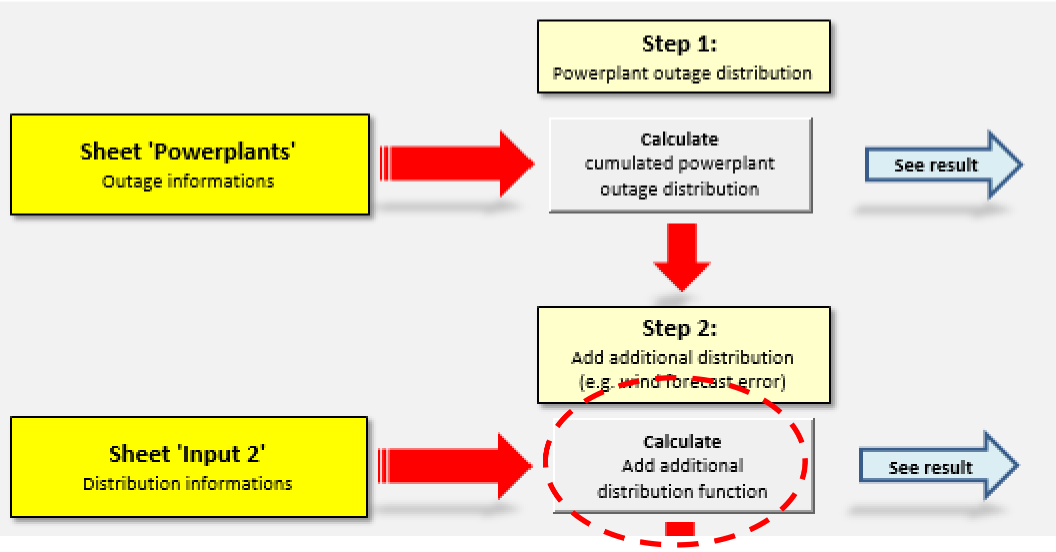
Additional distribution	
Error	Probability
-600,0 MW	0,10%
-410,0 MW	0,90%
-360,0 MW	1,20%
-300,0 MW	1,30%
-250,0 MW	2,40%
-230,0 MW	2,50%
-200,0 MW	4,60%
-150,0 MW	6,00%
-100,0 MW	10,30%
-80,0 MW	13,00%
0,0 MW	16,00%
50,0 MW	12,00%
100,0 MW	9,90%
150,0 MW	6,80%
200,0 MW	4,50%
250,0 MW	2,70%
300,0 MW	1,90%
320,0 MW	1,80%
390,0 MW	1,00%
460,0 MW	0,90%
550,0 MW	0,20%



In this example, we entered a distribution of wind forecast errors. The numbers mean, for instance, that with a probability of 0.10 %, the feed-in from wind will be 600 MW lower than expected, with a probability of 0.90 % it will be 410 MW lower than expected, …, and with a probability of 0.20 % it will be 550 MW higher than expected. The graphic on the right shows the probability density function.

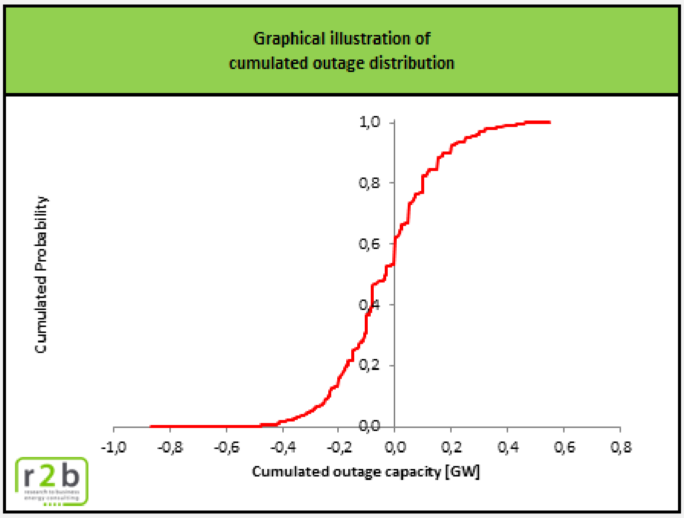
After having entered the distribution, klick the yellow button to return to the sheet "Analysis&Results".

In order to combine this distribution with the cumulated outage distribution of the power plants, you must now press the button under step 2:



The program will now perform a recursive combination of the existing cumulated outage distribution and the distribution that you just added. The result is again show on the right:

Cumulated Distribution		
Outage	Density	Cumulation
-868,0 MW	0,00%	0,00%
-839,0 MW	0,00%	0,00%
-838,0 MW	0,00%	0,00%
-834,0 MW	0,00%	0,00%
-809,0 MW	0,00%	0,00%
-805,0 MW	0,00%	0,00%
-804,0 MW	0,00%	0,00%
-783,0 MW	0,00%	0,00%
-778,0 MW	0,00%	0,00%
-775,0 MW	0,00%	0,00%
-754,0 MW	0,00%	0,00%
-753,0 MW	0,00%	0,00%
-749,0 MW	0,00%	0,00%
-748,0 MW	0,00%	0,00%
-744,0 MW	0,00%	0,00%
-724,0 MW	0,00%	0,00%
-720,0 MW	0,00%	0,00%
-719,0 MW	0,00%	0,00%
-715,0 MW	0,00%	0,01%
-714,0 MW	0,00%	0,01%
-693,0 MW	0,00%	0,01%
-690,0 MW	0,01%	0,01%
-685,0 MW	0,01%	0,02%
-678,0 MW	0,00%	0,02%
-664,0 MW	0,00%	0,02%
-663,0 MW	0,00%	0,03%
-659,0 MW	0,00%	0,03%
-649,0 MW	0,00%	0,03%
-648,0 MW	0,00%	0,03%
-644,0 MW	0,00%	0,03%
-634,0 MW	0,00%	0,03%
-630,0 MW	0,01%	0,04%
-629,0 MW	0,01%	0,05%
-628,0 MW	0,00%	0,05%
-619,0 MW	0,00%	0,05%



Tree nodes	500

Security level		Reserve Power
Power Outage	10,0%	238 MW
Excess Power	90,0%	200 MW

The tree now consists of 500 nodes, which is why not all nodes are shown in the picture above. However, the graphic at the top on the right shows the whole cumulated imbalance distribution. It now also contains positive values, i.e. values where – due to a potential wind forecast error – overall generation can be overestimated. This also changes the need for reserve power. In this example, given a security level of 10 %, 238 MW of positive (to cover unplanned power outages) and 200 MW of negative reserve power (to cover unplanned excess power) are needed. Again, you can change the security level, for example to 5 % (note that since this is the quantile of the cumulative distribution, the value of the upper quantile therefore has to be changed to 95 %):

Security level		Reserve Power
Power Outage	10,0%	238 MW
Excess Power	90,0%	200 MW

Now, 303 MW of positive and 250 MW of negative reserve power are needed.

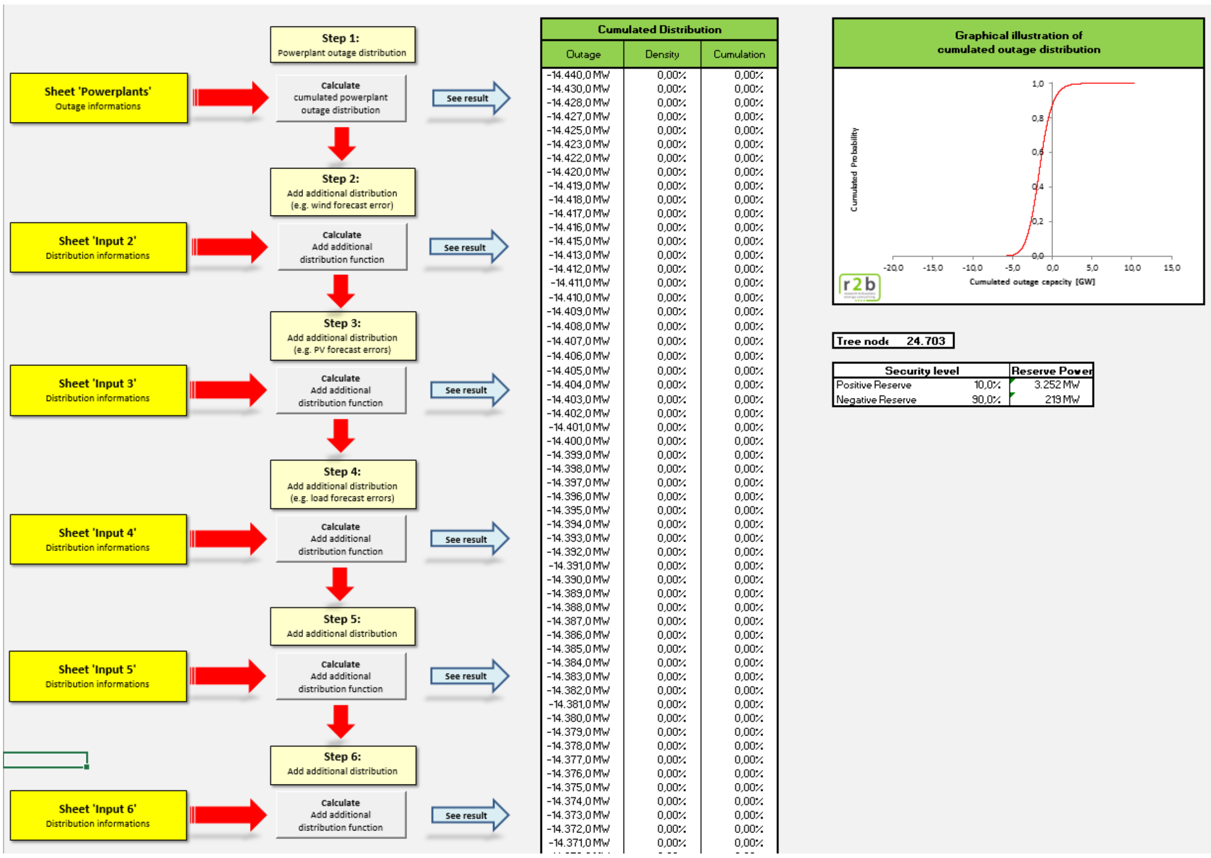
2.3 Step 3 to 6: Adding additional distributions

In step 3 to 6 you can (but do not have to!) add up to another 4 distributions. The procedure is exactly the same as in the previous step, i.e.

- Go to the input sheet by pressing the yellow button (again, the name of the input sheet can be changed if desired)
- Enter the distribution
- Got to the sheet "Analysis&Results" by pressing the yellow button
- Add the distribution to the cumulated imbalance distribution by pressing the "Calculate" button of the respective step.

Every time you add a new distribution by pressing the "Calculate" button, the program will perform a recursive combination of the existing cumulated imbalance distribution and the new distribution that was entered in the respective sheet. Thus, the more distributions you add, the bigger gets the cumulated imbalance distribution. There is a technical limit to this distribution (over 150,000 nodes), but under normal circumstance this should never be reached.

The next picture shows you a typical result of performing the calculations with 100 power plants and five additional distributions. In this case, the cumulated imbalance distribution consists of 24,703 nodes and – given a security level of 10 % – 3252 MW of positive and 219 MW of negative reserve power are required.



Note that – in theory and without an advanced calculation algorithm – the total number of nodes grows exponentially with the number of power plants and errors of each additional distribution. However, the underlying algorithm simplifies the tree and by that reduces the total number of nodes. This is done by combining nodes which have the same outage probability and summing up their probabilities. For instance, if an outage of 100 MW can occur both by the drop out of one power plant (100 MW with 3 % outage probability) and by an underestimation of wind power feed-in of

100 MW with 2 % probability, the algorithm will combine these two nodes to one node: Outage of 100 MW with the probability of 5 % (3 % by power plant outage plus 2 % by wind feed-in overestimation). This simplification of the tree is done each time an additional distribution is added. It requires a lot of computational power, but it strongly simplifies the result tree and the cumulated distribution. Thus, the resulting number of tree nodes does not grow exponentially.